Sborník vědeckých prací Vysoké školy báňské - Technické univerzity Ostrava
číslo 2, rok 2009, ročník LII, řada hutnická
článek č. 1504

CONTINUITY OXYGEN ACTIVITY AND TYPE NODULIZIER FOR DUCTILE IRON PRODUCTION

SOUVISLOST AKTIVITY KYSLÍKU S TYPEM MODIFIKÁTORU PŘI VÝROBĚ LKG

I. Nová[1], J. Morávek[2]

ABSTRACT: The article deals with measurements of oxygen activity ductile iron. The oxygen activity measurement proved, that oxygen activity in molted iron depends on technology of melting, chemical composition and temperature of the melt. The methodology of the oxygen activity measurement using TERMOSONDY Kladno TSO-FS (combined) sensors was developed at the Department of Engineering Technology Technical University of Liberec. The sensors were originally assigned for very low oxygen activity measured in molted steel. The EMF (ElectroMotive Force) and the temperature are sensor's output parameters used for oxygen activity calculation. Measured data are processed by the computer and results are displayed on the screen. All the results are saved in computer's memory together with the time of measurement. Oxygen activity is calculated using two formulas (ČSAV Ostrava and Electro Nite c.o.) at the time.

KEY WORDS: ductile iron, oxygen activity, melt, nodulizer.

KLÍČOVÁ SLOVA: litina s kuličkovým grafitem, aktivita kaslíku, tavenina, modifikátor.

1 INTRODUCTION

In the present-day we are devote the permanent attention on making the casts from ductile iron with spheroidal graphite, without inherent defect, demanded mechanical properties and structure. For fulfilment the demands of high quality of casts from LKG (ductile iron (cast iron with spheroidal graphite)) is contributing the chemical compound , but also metallurgical preparing of melt and cooling and solidification. Researches showed [2], [3], the big importance for quality production of LKG, have the inherence of oxygen. Oxygen have the fundamental proportion on all metallurgical processes making of steel and ductile iron. Monitoring of oxygen quantity in melt is the one of the most important load in metallurgical preparing of melt and simultaneously it is hypothesized that we can more qualification take control of metallurgical processes, first off modification and inoculation process. We are monitoring the oxygen activity in ductile iron melt at Faculty of Engineering, Department of Engineering Technology, Technical University of Liberec for a few years. In the present-day we are observing the relationship among used modificator and activity of oxygen and their effect on structure of making ductile iron.

2 OXYGEN AND OXYGEN ACTIVITY IN MELT GRAPHITE CAST IRONS

Oxygen in cast iron is present as a free (dissolved) and constrained in adducts, or more precisely in oxides. In metallurgy is free oxygen named as a active oxygen. We are monitoring his

1 Prof. Ing. Iva Nová, CSc. – Katedra strojírenské technologie, FS, TU v Liberci
2 Ing. Jiří Morávek, student Ph.D. – Katedra strojírenské technologie, FS, TU v Liberci

concentration, of more precisely active concentration otherwise ***activity***. Activity of oxygen is in melt of cast iron dependent on content of chemical elements, which have the big affinity to oxygen (for example C, Si, Mg, etc.). Activity of oxygen in cast iron is relatively small it means tenths ppm after modification.

Oxides (first of all SiO_2) have the function as a crystallization buds for graphite nucleation, HUMMER [1]. While the high temperatures SiO_2 and more stability oxides can be reduced by carbon. Reduction of oxides by carbon means lower number of crystallization buds, which is means worse graphitization effect, KUSAKAWA [3]. Higher contain of oxygen in melt have the tidy carbiditic effect.

Activity of oxygen in cast iron (cast iron with spheroidal and vermicular graphite) is monitoring for control force of modifications of melt before casting. In melt must be the sufficiency of modificator (Cu, Ce) for good modification effect. In melt of cast iron is existing the balance midst melted oxygen and magnesium. According to this regularity, i.e. according to quantity of melted magnesium and oxygen activity we can observing the force of modification on the base measuring of oxygen activity.

For measuring of oxygen activity in melts of iron is using the method measuring of electromotive tension (EMN) on galvanic cell, where solid electrolyte is fireproof oxide which has high ionic conductivity. In oxygen concentrate cell is also the referent material with known oxygen activity. Scheme of measuring sensing head for assesment of electromotive tension is in fig. 1.

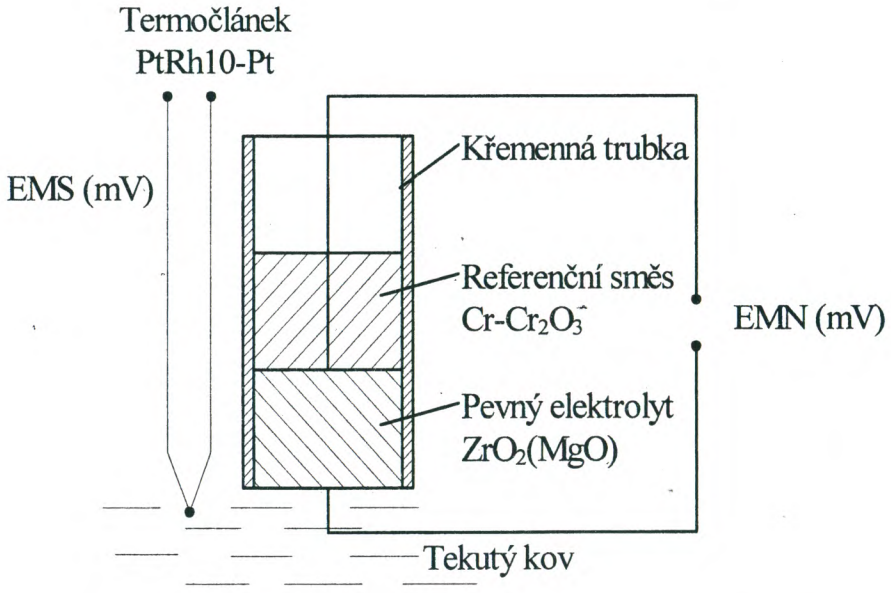


Fig.1 - Scheme of sensor measure oxygen activity and temperature in melt cast iron

Oxygen activity from measured value of EMN and temperature, we can establish on the base of equation, which is recommended by producer of sensing (TERMOSONDY s.r.o. Kladno) and it was compiled on ČSAV, workplace Ostrava:

$$\log(a_O) = 4{,}516 - \frac{13272{,}4 - 10080.(E + 0{,}025)}{T}, \qquad (1)$$

where is: T – temperature of melt [K];

E – electromotive tension [V].

or by the equation, which is recommend the foreign producer of sensing CELOX together with supplier of sensing Heraeus Electro-Nite:

$$\log a_O = 1{,}36 + 0{,}0059.[EMN.(T-1550) + 2.10^{-4}.EMN.(T-1550)] \qquad (2)$$

where is: T – temperature of melt [°C];

EMN – electromotive tensile [mV].

3 EXPERIMENTAL PROCEDURE OXYGEN ACTIVITY DURING DUCTILE IRON PRODUCTION

Objective of experiments was the observing of oxygen activity while using two kinds of modificators during producing LKG. In foundry KSP-FS, TU v Liberci was made two experimental melts. Melt was prepared in middle-frequention inductive furnace IO 40 from Indukce s.r.o., with acid furnace lining (SURACIT). Furnace charge was the raw iron SORELMETAL, his chemical compound is in table 1. In inductive furnace was melted 15 kg of raw iron coupled with 0,57 kg FeSi75 for increasing content of silicium.

Tab. 1 - Chemical composition of iron (SORELMETAL).

Compositiom [%]						
Fe	**C**	**Si**	**Ni**	**P**	**S**	**Ni**
95,48	4,23	0,15	0,013	0,07	0,026	0,01

Melt was in furnace warmed up on temperature 1550°C (measured by pyrometer). Nodulization was realized on the base of method SANDWICH, i.e. in special deep pot, which had the cover and acid lining (ACYKUP). The pot was served for casting. On the bottom of pot, against flown of metal, was placed the nodulizer (for melt n. I - VL 4, for melt n. II COMPACTMAG), inoculant FeSi75 under cover from cast iron spills. Chemical compound of nodulizer is in table 2. After ending of nodulization process the melt was additionally inoculated by graphitisation inoculant SUPERSEED. Chemical compound of graphitisation inoculants is in table 3 and chemical compound of melting charge for all melts is in table 4. After graphitisation inoculation and nodulization was measured the activity of oxygen, table 5. For this purpose was used the measuring equipment which was compiled on our workplace. For measuring was used combination sensing TSO-FS (producer TERMOSONDY s.r.o. Kladno). Chemical compound of produced cast iron was appointed by spectrometer (ZOS Liberec), table 6.

Tab. 2 - Chemical composition of the nodulizers

Chemical composition [%]				
COMPACTMAG				
Si	**Mg**	**KVZ**	**Ca**	**Al**
44 až 48	5 až 6	5 až 7	1,8 až2,3	max.1
VL 4 (FeNiMg)				
Fe	**Mg**	**Si**	**Ni**	
32 až 37	4,5 až 5,5	Max. 2	Zbytek	

Tab. 3 - Chemical composition of the used inoculants

Chemical composition [%]					
	Fe	Si	Al	Sr	Ca
FeSi75	75	25			
SUPERSEED		75	max.0,5	0,8	0,1

Tab. 4 - Charge composition

Materials for melting	Commercial name of materiál	Mass [kg]
Charge materials	SORELMETAL	15
	FeSi 75	0,57
		Mass in ladle [kg]
Inoculants	SUPERSEED 75	0,06
	FeSi 75	0,075
Nodulizers	VL 4 (FeNiMg)	0,24
	COMPACTMAG	0,24

Tab. 5 - Oxygen activity and temperatrure in molten cast iron after nodulazition and inoculation

Melt number	Type of nodulizer	Temperature of melting [°C]	Oxygen activity a_O [ppm]	
			by equation ČSAV (1)	by equation Electro-Nite (2)
I.	VL 4	1482	0,74	0,76
	VL 4	1390	0,31	0,49
	VL 4	1357	0,20	0,38
	VL 4	1322	0,13	0,31
II.	COMPACTMAG	1440	0,44	0,58
	COMPACTMAG	1395	0,28	0,36
	COMPACTMAG	1354	0,11	0,20
	COMPACTMAG	1314	0,07	0,14

In fig. 2 and 3 is showing dependences of oxygen activity on temperature of melt. Subsequently was observing the structures of cast iron from of both melts on lighting microscope Neophot 21. For highlighting of structure was used Nital 3%. Structures which was obtained from singles melts are show in fig. 4.

Tab. 6 - Chemical composition ductile iron after nodulizing and inoculation

Melt number	Chemical composition [%]								
	C	Si	Mn	P	S	Cr	Cu	Ni	Mg
after nodulizing									
I.	4,14	3,03	0,053	0,023	0,007	0,028	0,008	0,78	0,049
II.	3,89	2,62	0,043	0,024	0,009	0,027	0,008	0,79	0,045

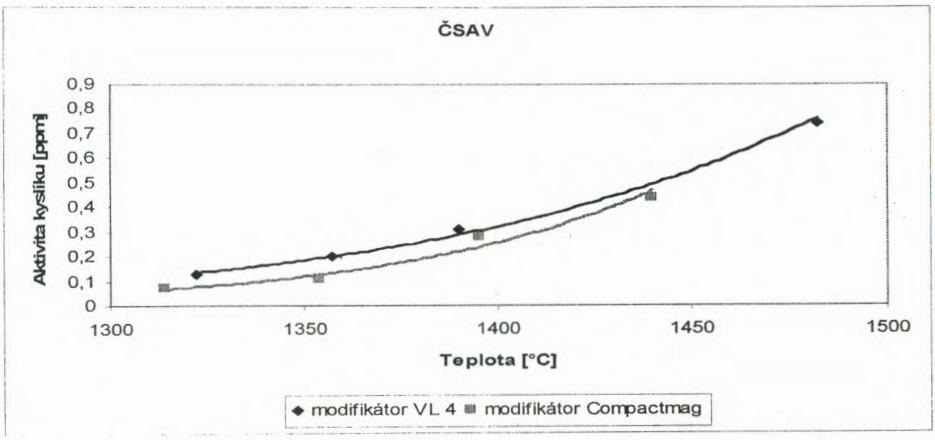


Fig. 2 - Dependence oxygen activity on the temperature after nodulization and inoculation ductile iron (oxygen aktivity calculus by equation (1))

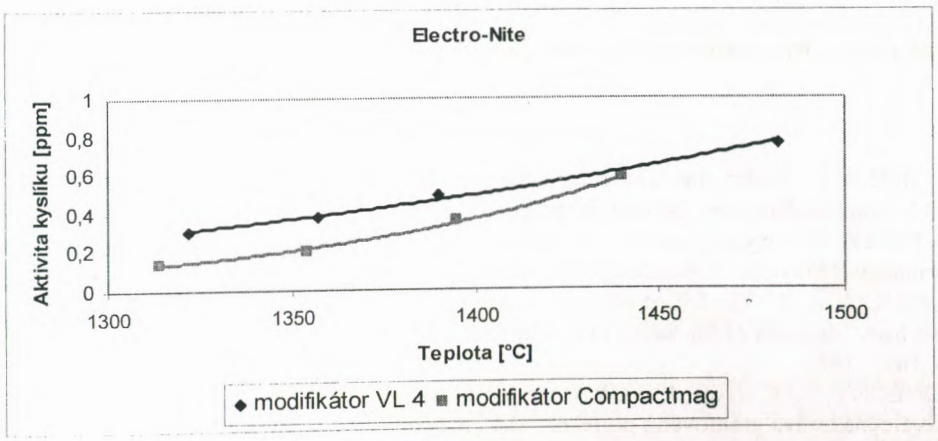
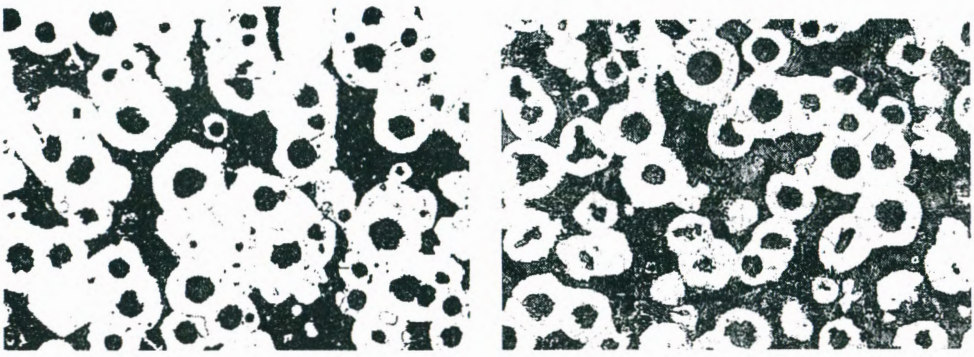


Fig. 3 - Dependence oxygen activity on the temperature after nodulazition and inoculation ductile iron (oxygen aktivity calculus by equation (2))



a) nodulizing (VL 4) **b)** nodulizing (Compastmag)

Fig. 4 - Structures of ductile iron casting

Structure of cast iron in fig. 4a) is corresponding to mark by ČSN 420461 50% VI6+50%V6-P80 and structure 4b) mark 60%VI6+40%V6-P45.

4 CONCLUSION

The activity of oxygen is an important criterion for determination kind of graphite and structure of cast iron. Oxygen activity is increasing with temperature, but it is dependent on charging raw materials and metallurgical condition of preparing of melt. While using the nodulizer on base FeNiMg, we can reach for ductile iron when temperature is 1400°C and realized activity of oxygen 0,31 ppm in melt after nodulization. When we using the nodulization Compactmag, we can have the ductile iron while realized activity of oxygen 0,28 ppm. Marked departures of this values show the rise of bad cast iron structure, i.e. bad kind of graphite or presence of free cementite in structure of cast iron.

The paper was created with a support of a reaserch plan MSM 4674788501

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